Gate-Tuneable Terahertz Transitions in Bipolar Waveguide and Double Quantum Well Structures in Graphene

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Despite its fascinating electronic properties, the main obstacle in using graphene in optoelectronics is the absence of a band gap which limits control of device behavior. We now show that bipolar waveguides [1] (formed from two narrow top gates with oppositely applied voltages) and double well structures (see Figure 1) in graphene, allows for the creation of a non-monotonous one-dimensional dispersion along the electron waveguide, which contains an electrostatically controllable pseudo bandgap. These pseudo bandgaps are typically of the order of terahertz and are associated with strongly allowed, highly anisotropic, terahertz transitions in a narrow frequency range.

We present a general theory of bipolar graphene waveguides, supported by numerical modelling, and confirmed by simple analytic estimates for exactly solvable potentials. We also solve and analyze the double-well problem for a family of quasi-one-dimensional potentials in terms of confluent Heun functions. By using the amazing property of Dirac materials, that a potential barrier can localize an electron, we show that unlike the trivial guided modes existing for both light and massive 2D electrons, we deal with purely Dirac/graphene physics opening the door to new optoelectronics applications. The potential applications of bipolar waveguides and double quantum well structures in graphene range from serving as the basis of polarization sensitive THz detectors, through to utilizing their unusual dispersion to create Dirac-Gunn diodes.

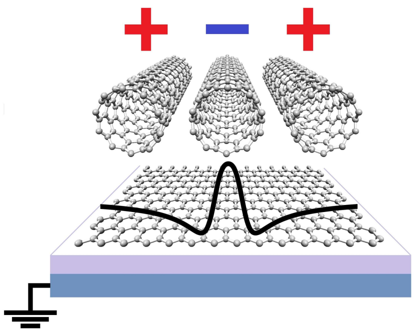

Figure 1. A schematic diagram of a double-well system created by three carbon nanotube top-gates. The central nanotube is negatively biased to create the central barrier, while the other two are positively biased to create the two wells. The Dirac material sits on top of a dielectric layer (violet layer), which lays on-top of the metal (gray layer). The Fermi level can be controlled using the back gate. The electrostatic potential created by the top-gates is shown by the thick black line.

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References

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